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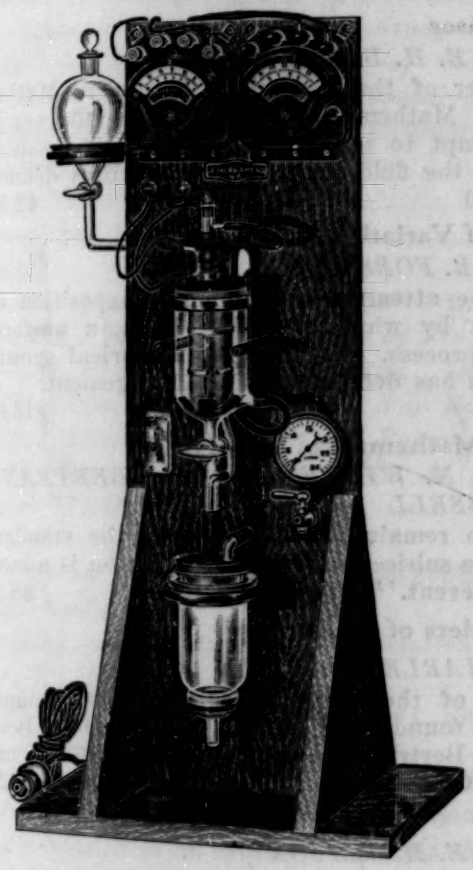

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MEDICAL RESEARCH AND ITS ORGANIZATION[1]

OCCASIONS such as the one in which we are participating are peculiarly significant. They mark the advancement of knowledge—its principles and practice—through a training of both the mind and the hand in the power to comprehend and extend knowledge. All knowledge comprises one vast domain; there is to-day scarcely a line of separation between the pursuit of the knowledge called "humanistic" and that called "scientific." The object is one, since in both what is sought is the interpretation of nature, whether in the physical world about us or in the mind and spirit within. In all these fields, we are now used to exercise the privilege of free inquiry and to substitute for authority the evidences of our perceptions.

This high privilege is on the whole a recent acquisition. Although we date our intellectual freedom from the Renaissance period, it is fruitful to reflect on the diverse ways in which the revival of learning in the fourteenth, fifteenth and sixteenth centuries affected on the one hand the development of letters and art, and on the other that of science. The interest awakened in the literature of Greece and Rome was shown in the admiration not only for the works of poets, historians and orators, but also for those of physicians, anatomists and astronomers. In consequence, scientific investigation was almost wholly restricted to the study of the writings of authors like Aristotle, Hippocrates, Ptolemy and Galen, and it became the highest ambition to explain and comment upon their teachings, almost an impiety to question them. Independent inquiry and the direct appeal to nature were thus discouraged, and indeed looked upon with the utmost distrust if their results ran counter to what was found in the works of Aristotle and Galen.[2]

It is not without significance for us that it was the anatomists of the sixteenth century who broke with tradition and determined to examine the human body for themselves, and it was owing chiefly to the labors of two independent geniuses, contemporaries for a time at the University of Padua, Galileo and Harvey, working in very different spheres, that the old order was overthrown and a new era inaugurated.

For medicine as well as for the physical sciences

[1] Address made at the Convocation for the Conferring of Advanced Degrees, Brown University, June 14, 1927.

[2] Harvey, W., "Motion of the Heart and Blood in Animals," translated by Robert Willis, Everyman's Library, 1906; Introduction by E. A. Parkyn, p. vii.

these two men were of supreme importance. From Harvey's discovery of the movements of the heart and blood vessels dates not only the science of physiology, but that of medicine itself. It has been well said that this great discovery stands to medical practice much in the same relation as the discovery of the mariner's compass stands to navigation.[3]

Harvey's epochal book was published in 1628. It seems probable that he began teaching his doctrines to his classes as early as 1616—the year of Shakespeare's death. For more than ten years, Harvey delayed any formal publication of his experiments and deductions, meanwhile inviting criticism and opposition to his views from all sources, in order that the complete truth, free from any falsities and misconceptions, might be disclosed. To-day as it did then, his modest treatise stands as a landmark in human history, and a perusal of the methods of experiment employed and the mode of presentation adopted arouses feelings only of admiration and emulation. The fundamental thesis of Harvey's teaching is expressed in almost winged words by a modern physiologist:[4] that only by searching out and studying the secrets of nature by way of experiments can we hope to attain in the words of Job "to a comprehension of the wisdom of the body and the understanding of the heart," and thereby gain that mastery of disease and pain which will enable us to relieve the burden of mankind.

The announcement of the discovery produced a sensation; it was opposed, but not by the younger physicians. Among those who discerned its significance was the philosopher Descartes. The material effect was not fortunate. Harvey's medical practice fell off. Patients feared to put themselves under the care of one accused by the ignorant and envious of being crack-brained, and of putting out new-fangled and dangerous doctrines. This fate of great innovators is still not unknown. There was fortunately one man in a high place who showed lively interest in the discovery. Charles I supported Harvey and appointed him his personal physician. It is interesting to reflect that this monarch, whatever opinion may be held of his other qualities, by aiding Harvey and Van Dyke showed himself an enlightened patron of art and science.[5]

Hardly more than half a century separates the astounding figure of Harvey from the overwhelming figure of Newton—"the lawgiver of the universe" in the phrase of his contemporaries. Both men w enemies of mere speculation, and upholders of the perimental method, and both were conspicuous by son of the extreme caution with which they prom gated their discoveries. Newton even less than H vey was possessed of the passion, verging on fana cism, for scientific discovery which has distinguish many men. He had almost to be cajoled into enunciation of the discovery of the law of gravitat and he all but failed to complete the *Principia*, cause he detested controversy.

"I see I have made myself a slave to philosophy will resolutely bid adieu to it eternally, except wh do for my private satisfaction, or leave to come after me; for I see a man must either resolve to out nothing new, or become a slave to defend it."

Newton's objectivity was extraordinary; in spite the wonderful success of his theory he did not th that the law of gravitation was the final expres of gravitational phenomena—a piece of scientific tion which we have seen justified in our day.

To those of us charged with the responsibility searching out scientific aptitude, it is wholesome learn that the reflective youth, unlike most g mathematicians, gave no evidence of mathema precocity. Even when at nineteen he entered C bridge he had no definite intention of studying ma matics; it was the chance picking up of a book astrology at a country fair which turned his mind this direction, and yet when he took his B.A. de four years later he had discovered the bino theorem and invented the differential calculus.

The past one hundred years have seen the tri of the experimental method; the deepest problem which we are aware have been explored with c dence because of the perfection of method and o struments of extreme precision. In the phy world we stand in awe of the marvels being ac plished as, to take two or three spectacular exam in the field of atomic structure, of radiology an aviation. The medical biological field is also b cultivated, with results no less significant perhaps science as a whole.

Since the greater speed of discovery has come the last half century, it may be of interest to in briefly into some of the advances in medical sci with which subject I am myself more familiar. this science should have lagged somewhat and in still grows more slowly than the mechanical and p cal sciences need scarcely evoke comment. As wa marked by Claude Bernard,[6] "the object of scien

[3] Simon, Sir John, "Motion of the Heart and Blood in Animals," Everyman's Library, 1906; p. ix, Editor's Introduction.

[4] Starling, E., *Lancet*, 1923, ii, 869.

[5] Harvey, W., "Motion of the Heart and Blood in Animals," Everyman's Library, 1906; p. xviii, Editor's Introduction.

[6] Bernard, Claude, "An Introduction to the Stud Experimental Medicine," English Translation, p. 67.

everywhere the same: to learn the material conditions of phenomena. But though this goal is the same in the physico-chemical and in the biological sciences, it is much harder to reach in the latter, because of the mobility and complexity of the phenomena which we meet." Under these circumstances it is no wonder that at a period when the physical sciences were being enriched by experiment, medicine still remained a subject of philosophical systemization—a condition called by the philosopher Locke the Romance-way of physic, because it is more easy for men to build castles in the air of their own than to survey well those that are on the ground.[7]

It is usual to date the beginning of what we are pleased to call the present or modern era of medical research from the establishment of the germ origin of disease. In truth, no such sharp distinction as this is to be drawn; the germ theory of disease is a logical outgrowth of the state of development of chemistry and physiology in the middle period of the nineteenth century, and those two sciences had contributed then, as they continue to contribute in ever-increasing volume, to the store of biological knowledge.

And yet there is truth in the view that new impetus and new hope were suddenly brought into medicine through the pregnant discoveries of Pasteur, Lister and Koch, which did so much to aid the growth of preventive and curative medicine. The pursuit of microbiology, the science of the infinitely little, is still under full swing. The quest has broadened greatly within the past few years. The mere study of the elusive parasite has given way to a much more searching investigation of its intimate properties, its precise chemical constitution, on which depends its power for inflicting injury, and on a real understanding of which rests man's power of defense against harmful action; and the knowledge already gained in this difficult field is of very great significance. The quest is also taking into account a remarkable capacity for variation among these minute parasites, affecting their propensity for inducing disease and raising far-reaching questions as to the origin of the parasitic forms and their relation to the far greater number of non-disease producing microbes with which man in common with all living things lives in intimate daily communion.

The newer studies have brought the knowledge of parasite and host, the animal and plant, into closer and more equitable relationships, and have thus shown a way by which epidemics on an experimental scale may be profitably investigated among laboratory animals and made to yield information valuable in itself and even informing in respect to epidemics in man.

[7] Brown, John, Horae Subcivae, 1st Series, p. 19.

Perhaps no subject of wide investigation has yielded more startling and valuable information than that relating to the physiological effects of the so-called internal secretions. If indeed we wish to correlate present-day outlook in medical practice with earlier happenings, we could choose no more fecund example than the master work of Claude Bernard on the sugar-liberating functions of the liver, to which he first applied the phrase. Contemporary investigation by physiological and chemical means of this class of substances, the chemical messengers, or so-called hormones of the body, through which many of its functions are integrated, has been rich in surprising rewards. Almost everyone is familiar with the relationship of the "stunted, pot-bellied, slavering cretin,"[8] with defect of the internal secretion of the thyroid gland, and we stand awed before the now common fact of the transformation of the cretin into a normal, comely, intelligent child merely by the administration of the substance of the thyroid gland of animals. And we are growing familiar with the instances of gigantism and of excessive obesity, resulting from pathological conditions of the complex pituitary gland, the small body which sits on the fantastic Turkish saddle at the base of the brain. The physiological effects as well as the practical uses of epinephrine, the peculiar secretion of the adrenal glands, would seem to bear daily testimony to that regulatory mechanism, through which fear is expressed and courage reinforced; while the saving graces of insulin, the hormone regulating the sugar consumption of the body, have rendered the lives of many thousands of victims of diabetes tolerable and happy. This is a very incomplete list of even our present knowledge of these subtle, integrative, chemical messengers of health and disease. Others regulate at the proper moment the order of the digestive secretions, determine secondary sexual characteristics, and even stand watch and ward over the generation of human life itself.

There is no sharp line between health and disease, and no sharp distinction between the functions called physiological and pathological. A knowledge of the body will include all the biological processes with which we can deal. The animal body has often been compared to a watch, and the physician with the expert watchmaker, and it has been hoped that in due time doctors will be as good at their craft as watchmakers are at theirs. It is true, of course, as John Brown, the gifted author of "Rab and his Friends," has pointed out, that the watchmaker is not called on to mend the watch while it is going, and that this makes all the difference. But the simile is far more

[8] Starling, E., *Lancet*, 1923, ii, 869.

imperfect than this, since the most cunning of Swiss watches which tolls the precise minute of the day or night, shows the day of the month, the quarters of the moon, and even other successive events, is so far simpler than the beautifully constructed and ingeniously integrated animal body, that it is almost an offense to compare one with the other.

The vocation of medicine is multiple; hence the need for specialization. In recent times, the scientific medical investigator has also become a specialist. Since medicine is one of the biological sciences, it is natural to ally it with biology as an educational discipline. But this definition has become too narrow. The growth of medical science, as a biological science, has brought it into more and more intimate relationship, first with classical chemistry and now with classical physics, to the great benefit of both medicine and biology. A generation ago we saw the rise of biochemistry as an independent subject of research and knowledge; to-day we are witnessing the beginnings of biophysics as a similar independent subject. There is hardly a direction in which classical chemistry and classical physics are moving forward, in which biology and medicine do not promise presently to follow.

These circumstances call for specially trained men possessing the temper and aptitudes of the investigator to pursue medical research. Indeed, so formidable has become the demand for the investigation of medical problems that particular provision is being made in universities and special institutions founded to fulfill this demand. On all sides the persons with these qualities are being scrupulously sought in increasing numbers. In order to provide for them the most favorable opportunities for work, a kind of organization of research is being undertaken. This is a new thing as a purely scientific experiment, and hence it may be well to inquire just what is embraced under the term of "organized medical research."

There are known conditions under which scientific discoveries have been made in the past. The strong individuality of the gifted investigator is well illustrated by the two extreme examples dealt with at the beginning of this address. It were futile to attempt any organization which purposes to promote discovery by such persons as these. Indeed, it is not intended at all, and probably would prove impossible ever to organize the subject-matter of research and the extraordinary minds which are the chief means of making discovery. It is now recognized that the progress of science, while strictly logical, is not uniform. The whole body of scientific knowledge does not move and can not be moved forward on a wide front. As a matter of fact, the reverse process occurs; progression takes place now at one, and now at another part of the front—after which, and perhaps slowly and with great effort, the rest of the column moves on. In the meantime, still another thrust occurs, and now perhaps at a new part of the line, necessitating a still further general readjustment.

And so with an infinity of pushes and pauses, owing to the efforts first of one and then of another group of investigators, and at different periods, one observes a larger problem to be cleared, but perhaps never completely solved. As Newton has said, physical laws deal with relations between phenomena, not with causes; and causes need not be mathematical at all. Moreover, the physical laws we enunciate must be regarded as provisional and approximate. Hence the progress of science means the closer and closer approximation to the objective—perfect, immutable laws.

The first indications of an experimental advance may occur many years ahead of the explanation of the phenomena involved, and until the latter appears, the real significance of the discovery may be missed. Thus, Hopkins observed that small animals failed to develop normally on a carefully balanced, adequately caloric diet, not imagining the fault to lie with the want of almost imponderable quantities of necessary vitamines, substances still of elusive chemical composition, the existence of which at the time was unknown. Now we designate with almost a half dozen letters of the alphabet as many supposedly vitamine entities which control as many physiological and pathological functions of the animal body.

In like manner when the remarkable power of cod liver oil to prevent rickets in the young had been clearly shown, no one could have suspected that a like effect was produced by certain rays of the sun, and even less that in both instances the beneficial action is determined by a reciprocal, quantitative relation in the phosphorus-calcium content of the blood. Just now that the study of radiation effects—of X-ray and of radium emanations—is claiming so much attention, we wish to ascertain what it is that takes place, which on the one hand leads to that kind of injury of animal cells that sometimes produces cancerous conditions, and on the other the beneficial changes that result in the actual cure of pre-existing cancerous growths. That the radiations alter in some way the physiology of cells—normal or cancerous—may be assumed; it is the how that is being sought, and the nature of the alterations induced. The ability to grow animal cells indefinitely outside the body has provided an almost perfect material for the biological testing of the effects of physical and chemical agents, from which in due time a new cell physiology will doubtless emerge.

Among investigators the rarest are those men with

a presentiment of new truths; the far greater number merely develop and follow the ideas of others. In a few instances the presentiment is extraordinary, but it is always likely to be a brilliant example of the scientific use of the imagination. Of the first order of magnitude was Harvey's assumption of the existence of minute vessels uniting the arteries and veins and completing the circuit of the circulation. In his day the microscope was too primitive to reveal them; in fact, Malpighi's discovery of the capillaries occurred four years after Harvey's death and thirty years after the publication of the "Motion of the Heart and Blood in Animals."

At all periods, voices have occasionally been raised to decry the domination of medicine by science. These timid souls would return to the less aided senses in order to provide the so-called intuitive faculty of the physician with greater latitude. Just now this thesis has been put forward by an eminent German surgeon—Sauerbruch—and an active controversy has been started. The weight of opinion, fortunately, is more modern and logical, for while it is properly admitted that superficial science can never compensate for slipshod observation, and while it is allowed that one doctor's wits are sharper and quicker than another's, yet it is urged with easy conviction that without true knowledge even the supremely intuitive can reach no real goal nor pass beyond the limits of the "inspired ignoramus."

If, therefore, we may not seek to organize the subject-matter of research, we may nevertheless undertake to organize the facilities which make the prosecution of research more consistent and less a matter of chance. In carrying out this purpose, we must ever keep in mind that the outstanding discoveries in science are the accomplishments of real men and usually of great men. Now, as it has been well said, great men are just those who bring with them new ideas and destroy errors. They do not, therefore, respect the authority of their predecessors and they do not move in an ordered way. While it is of course true that the discoveries of the great men preceding them stand at the base of their own discoveries, yet neither is ever the promoter of absolute and immutable truths. "Each great man belongs to his time and can come only at the proper moment, in the sense that there is a necessary and ordered sequence in the appearance of scientific discoveries. Great men may be compared to torches shining at long intervals to guide the advance of science. They light up their time, either by discovering unexpected fertile phenomena which open new paths and reveal unknown horizons, or by generalizing acquired scientific facts and disclosing truths which their predecessors had not perceived. If each great man makes the science which he vitalizes take a long step forward, he never presumes to fix its final boundaries and he is destined to be outdistanced and left behind by the progress of successive generations. Great men have been compared to giants upon whose shoulders pygmies have climbed, who nevertheless see further than they. This simply means that science makes progress subsequently to the appearance of great men, and precisely because of their influence. The result is that their successors know many more scientific facts than the great men themselves knew in their day. But a great man is, none the less, still a great man, that is to say—a giant."[9] And who would presume to confine, that is to restrict by organization, a band of giants? It is enough to provide them, as they may now hope to be provided, with suitable material resources with which to perform their gigantic, wonder-working tasks, of which they are often the unconscious agents. This, and as it seems to me, this alone is the purpose and the justification for the organization of science: to afford opportunity commensurate with the objects to be attained, for both the giants and their associates of smaller stature, for him who blazes the trail and him who clears the path, since both operations are needed in order that knowledge may be increased and the light be made to enter the still dark places, and the spirit of man be thereby enlarged and made to shine with ever greater brilliance.

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[9] Bernard, Claude, "An Introduction to the Study of Experimental Medicine," English Translation, 1927, p. 41.

SCIENTIFIC EVENTS

THE CONVERSAZIONES OF THE ROYAL SOCIETY

THE first of the two conversaziones given annually by the Royal Society has taken place at Burlington House, when, as usual, an array of exhibits was provided for the instruction and entertainment of the visitors.

According to an article in the London *Times* one of the most striking demonstrations was that of Mr. A. A. King, who showed the application of ultra-violet radiation from a mercury vapor lamp to the detection and estimation of minute quantities of arsenic. When a mercury-arsenic stain on a piece of filter-paper sensitized with mercuric chloride is examined in ultra-violet light the unchanged mercuric chloride fluoresces blue, while the mercury-arsenic stains stand out as a black disc. Arsenic stains,

which are quite invisible in ordinary light, may be revealed in this way, and it is said to be possible to detect and estimate quantitatively amounts of arsenic as small as 0.00001 of a milligram. Impurity in distilled water is also revealed by fluorescence in ultraviolet light, and it has not yet been found possible, even with the most refined methods of distillation, to prepare water that does not show some sign of fluorescence. An exhibit from the National Physical Laboratory also illustrated the difficulty of preparing substances in a state of absolute purity. It included specimens of iron, manganese and chromium, the impurities in which are detectable only with the spectroscope.

Another exhibit from the National Physical Laboratory showed the structure of pure mercury in the solid state, the metal being kept frozen by liquid air or carbon dioxide snow and acetone and etched with a solution of hydrochloric acid that does not freeze at the temperatures employed. A collection of metallurgical specimens exhibited by Sir Robert Hadfield included sections from reinforcement bars of high tenacity non-corrodible steel, which are being used in the preservation work at St. Paul's to replace the original wrought-iron bars put in by Sir Christopher Wren.

Bolometers responding with remarkable rapidity to radiant heat were shown by Mr. H. Dewhurst; they consist of a narrow strip of bismuth, believed to be only 0.0000007 cm. thick, deposited on thin celluloid films by electrical evaporation. The thermostat of Lieutenant-Commander F. J. Campbell Allen and Mr. A. E. Salisbury depends on the fact that magnetic metals lose their magnetic properties at certain temperatures; in the apparatus an armature normally attracted by the metal drops as the temperature of the metal is raised, to be attracted again when the temperature falls.

Other physical exhibits included apparatus devised by Professor O. W. Richardson and Mr. F. S. Robertson for comparing the yield of soft X-rays from different substances; a demonstration by the British Thomson-Houston Company of the phenomena produced by an arc in a hot cathode discharge tube containing argon when tungsten vapor is injected; the Selényi method of measuring the vacuum in a lamp and new methods of using gas-filled photoelectric cells, one enabling very small illuminations to be detected without any delicate apparatus, and the other suitable for picture telegraphy, by the Research Laboratories of the General Electric Company; and apparatus for analyzing gases by means of high-frequency vibrations and for estimating flame temperature by spectrum line reversed, by the National Physical Laboratory.

AN INTERNATIONAL SOCIETY FOR THE STUDY OF PEATLANDS

AN international organization for the study of peatlands (Moorforschung) has been formed as a subcommission of Commission VI of the International Society of Soil Science. The object is to promote peat investigations on an international basis and to coordinate and develop, in cooperation with governmental, state and private agencies such research and uniformity of methods in laboratory and field practices as are deemed in the interest of the fullest investigation, utilization and protection of peatland resources. The work of the organization is to be carried on by the following officers: Dr. A. P. Dachnowski, U. S. Department of Agriculture, chairman; Dr. Hugo Osvald, director Peat Experiment Station, Jönköping, Sweden, secretary; Professor Dr. B. Tacke, Germany; Colonel J. Girsberger, Switzerland; Dr. L. von Post, Sweden; Professor S. H. McCrory, Washington, D. C.; Dr. F. J. Alway, Minnesota, U. S. A.; Dr. W. S. Dokturowski, U. S. S. R. (Russia); Dr. A. Kirsanov, U. S. S. R. (Russia).

Cooperation has been assured by an International Peat Committee which consists of leading members well known for their investigations in the geographical distribution of peatlands, in paleobotany, stratigraphy, agronomy, forestry, engineering and other special phases of peatland utilization.

The formation of the organization was initiated at informal conferences with directors of peat institutes and peat specialists in several countries of Europe. The proposal was made and approved of holding a special peat session in the United States and organizing during the sessions of the First International Congress of Soil Science, held in Washington, June 13 to 22, 1927.

The value of the special peat session just closed was shown by the interest in an exhibit of different types of peat and profile sections of peat areas, and by the commission's formal recognition of the advantages of genuine international action in common projects. It aims at the coordination of fundamental peat investigations with the practical technique of utilizing areas of peat for different purposes. At its final session the Congress recommended to secure uniformity of methods of procedure for the investigation and handling of peatlands, with the ultimate aim of obtaining an accurate determination of the agricultural and industrial possibilities of peatland resources throughout the world.

Persons engaged in any aspect of this subject and desiring to associate themselves with the work of the international sub-commission are invited to join as members. Communications may be addressed to Dr.

P. Dachnowsky, U. S. Department of Agriculture, Washington, D. C.

AN AGRICULTURAL CENSUS OF THE WORLD

An agricultural census of the world is planned der the direction of Mr. Leon M. Estabrook, of the ternational Institute of Agriculture at Rome. Plans re prepared and approved by the general assembly the institute in April, 1926.

Since June, 1926, Mr. Estabrook has been visiting inisters of agriculture and heads of the statistical visions of various governments in regard to the oject.

All European countries and surrounding countries, cluding Russia, Turkey, Syria, Palestine, Egypt and North African Colonies, have promised coopera- in taking the census, France offering the most tential difficulties. The European nations also mised to aid the institute in obtaining the coopera- of the colonies.

Mr. Estabrook is visiting Canada at the present e and will proceed to Mexico, Cuba, Jamaica, aiti, Santo Domingo, Porto Rico, Panama and nce across the Pacific to Hawaii, Japan, China, do-China, the Philippines, Dutch East Indies, Aus- lia, New Zealand, India and the countries west, in- ding Arabia and others, to the colonies of eastern rica. He will then proceed to South Africa and nce to South America. He hopes to return to e, having completed the circuit of the world and ited practically every country, in time for the meet- of the general assembly in October, 1928.

This is the first attempt ever made to induce all ntries to take an agricultural census. Out of the countries listed by the International Agricultural titute, only 60 have ever taken an agricultural cen- and less than 40 have taken one since 1900. Of not more than four happened by chance to take nsus in the same year, and no two have taken their us in the same manner.

If the present attempt is successful, the institute es to obtain funds for its continuation, with col- on of statistics every ten years.

Each country has agreed to pay for its own census to issue its own report, which will be utilized in paring the institute world report for each product.

THE GEOLOGIC SURVEY OF PENNSYLVANIA

The Topographic and Geologic Survey of Pennsyl- ia is carrying on the following projects during present field season in addition to the cooperative ographic work:

G. H. Ashley. Preparing a popular report on the rocks of Pennsylvania.

R. W. Stone. Field work on building stones of Pennsylvania.

J. D. Sisler. Detailed reconnaissance of the oil and gas fields of Pennsylvania.

Anna I. Jonas. Detailed areal mapping in the Middletown and York quadrangles, with some cooperation from George W. Stose, of the United States Geological Survey.

Herbert Hughes. Detailed areal mapping of the Freeport quadrangle.

Frank Leverett, of the United States Geological Survey. Cooperative study of glacial geology, especially that outside the terminal moraine.

George H. Chadwick. Stratigraphic studies in the oil and gas region of northwestern Pennsylvania.

Henry Leighton, University of Pittsburgh. Studies in the clay deposits of Pennsylvania of the Pittsburgh district, with field and laboratory studies by Professor J. B. Shaw at State College.

Charles R. Fettke and W. A. Copeland. Detailed plane-table mapping and studies in the Bradford oil field.

Freeman Ward, Lafayette College. Areal studies of the sand and gravel deposits of Pennsylvania.

Charles H. Behre, Jr. Detailed studies of slate west of Lehigh River.

Arthur M. Piper. Underground water resources of northwestern Pennsylvania.

On May 7 the state printery was nearly destroyed by fire. The survey's remaining stock of bulletins was on the third floor of this building and practically all destroyed. It is hoped that the more recent of these bulletins may later be reprinted from insurance funds.

FIELD EXPEDITIONS OF THE UNIVERSITY OF CHICAGO

Field expeditions from the University of Chicago have started on divergent trails to study scientific records of America in anthropology, geology, archeology and paleontology.

Professor Fay-Cooper Cole, of the department of anthropology, will continue the extensive study of the Illinois mounds which he began last year. Illinois, according to Professor Cole, is the key state in anthropology for prehistoric America. His work this summer will be part of a program that may take ten years to complete. Information will be gathered on the mounds of the state by advanced students under his direction, and some preliminary excavations will be made.

Paul Miller, curator of Walker Museum, will continue his research on dinosaurs and other extinct animals in an area of east-central Wyoming.

Professor Edwin Sapir, of the department of anthropology, and Fang-Kuei Li, Chinese student, will

study the language of a group of Hupa Indians in northwestern California. Li, who is specializing in linguistics, is working under the committee on American Indian languages of the Council of American Learned Societies. He will teach Chinese at the university next year.

A group of twenty-five students from a dozen universities and colleges met in June at the University of Chicago geological field station near St. Genevieve, Missouri, for a period of intensive study under Professor Stuart Weller. The site and buildings were presented to the university by W. E. Wrather, an alumnus.

Professor J Harlen Bretz, also of the department of geology, will continue studies of an area of 12,000 square miles in Washington, south of the Spokane River and east of the Columbia. Six graduate students and one undergraduate will assist him during part of the study.

Several members of the department of geology will work under the State Geological Survey, Dr. Paul McClintock continuing a detailed study of Illinois glacial deposits, and Dr. Jerome Fisher studying oil and gas possibilities in the southeastern part of the state. Associate Professor A. C. Noé, paleontologist, who is now in Russia engaged in the investigation of coal mines for the government, will later conduct a course on fossil plants in the coal fields of Illinois, Indiana and Kentucky.

A field class under the direction of Professor Edson S. Bastin, chairman of the department of geology, is now at work in the region of Devil's Lake, Wisconsin. Later Professor Bastin will complete a study of fluorspar deposits of Illinois and begin work on the asbestos deposits south of Quebec.

RESOLUTIONS IN MEMORY OF VICTOR LENHER

A MEMORIAL resolution in honor of Dr. Victor Lenher, late professor of analytic and inorganic chemistry at the University of Wisconsin, was adopted at the last meeting of the faculty. Introduced by Professors R. Fischer, C. K. Leith and J. H. Mathews, it recalls the life and labors of Dr. Lenher, who died on June 12, 1927, at the age of fifty-four years.

Professor Lenher was called to the University of Wisconsin as assistant professor of general and theoretical chemistry in 1900; he was previously at Columbia University. In 1904 he became associate professor and in 1907 he was made professor. The resolution reads further:

> For fourteen years he was a member of the board of education of the city of Madison, and for two years he was a member of the state board of health. His constant interest in municipal and state affairs was of inestimable value to the city and to the commonwe During the early part of the world war, he interes himself in researches on gas warfare in collaborati with the bureau of mines and the gas service. Later was commissioned as major in the chemical warf service and served first as chief of university relatio and later as adjutant on the staff of Major-Gene Sibert, director of the chemical warfare service. He w honorably discharged, December 5, 1918.
>
> In the study of the chemistry of gold, tellurium a selenium, he reached preeminence. His researches on t chemistry of these elements number over 60, coverin period of over twenty-five years.
>
> The resolution eulogizes Professor Lenher as an ed cator and for his interest in students, and continues
>
> In the death of Professor Lenher, the university h suffered an irreparable loss. He came to the univers at a time when strong, capable men were specially need the beginning of a period of rapid expansion. He n only lived through this most interesting quarter-cent of development of the university, but contributed larg to the wise direction of that development. His l though shortened by an untimely death, was a full a and a happy one; he enjoyed his work, his studen his associates, and his family. He has left an imperi able record of achievement of which the University Wisconsin will ever be proud.

SCIENTIFIC NOTES AND NEWS

DR. WHITMAN CROSS, from 1888 to 1925 geolog of the U. S. Geological Survey, and Professor A. Högbom, of the University of Upsala, have b elected foreign members of the Geological Society London. Professor F. X. Schaffer, University Vienna; Professor C. Schuchert, Yale Univers Professor F. Slavik, University of Prague, and Dr. O. Ulrich, of the U. S. Geological Survey, have b elected foreign correspondents.

DR. ROBERT A. MILLIKAN, of the California In tute of Technology, sailed for Geneva on July 1 attend a meeting of the Committee on Intellectual operation of the League of Nations.

DR. W. D. MATTHEW, who recently resigned as h curator of the geological sciences in the Ameri Museum of Natural History, has arrived in Berk to take up his work as professor of paleontology head of the department in the University of C fornia.

A COMMISSION from the medical faculty of the U versity of Havana is visiting the United States Canada as the guest of the Rockefeller Foundati The commission includes the following: Dr. Sol Ramos, dean and professor of biological chemis and chairman of the commission; Dr. Carlos Fin professor of ophthalmology, representing the clin

subjects in medicine. Dr. Finlay's father was among the first to suspect that yellow fever was transmitted by the Stegomyia mosquito; Dr. Aristides Agramonte, who has been acting dean of the medical school and who was a member of the original yellow fever commission; Dr. Felix Martin, professor of the school of engineers and architects, who is in charge of planning for the new medical buildings to be erected by the Cuban University. The commission will spend about eight weeks visiting medical institutions in the United States and Canada.

PAUL C. MILLER, paleontologist in the Walker Museum of the University of Chicago, has been made a Knight of the Order of Danebrog by the King of Denmark.

WARREN K. MOOREHEAD, director of the department of archeology at Phillips Academy, recently received the honorary degree of doctor of science from Oglethorpe University, in recognition of work in American archeology.

DR. EDWARD W. ARCHIBALD, director and professor of the surgical department of McGill University, was recently made an honorary fellow of the Royal College of Physicians of London.

THE title of emeritus professor of anatomy in the University of London has been conferred on Professor Edward Barclay-Smith as from the end of the session 1926–27, when he retires from the university chair of anatomy tenable at King's College.

DR. EDWIN GRANT CONKLIN, professor of biology at Princeton University, has been elected a member of the board of directors of the American Eugenics Society.

DR. H. H. DALE, head of the department of biochemistry and pharmacology in the National Institute for Medical Research at Mount Vernon and a secretary of the Royal Society, has been nominated to be for five years a member of the General Council of Medical Education and Registration.

PROFESSOR HENRY LOUIS, of Newcastle, was appointed by the council of the Institution of Mining Engineers at their summer meeting at Newcastle to succeed Dr. J. S. Haldane as president at the annual meeting in London in November.

THE following have been elected officers of the Manufacturing Chemists Association for the ensuing year: *President,* Henry Howard, Grasselli Chemical Co.; *Vice-presidents,* W. D. Huntington, Davidson Chemical Co.; H. A. Galt, Columbia Chemical Division, Pittsburgh Plate Glass Co.; *Treasurer,* Phillip Schleussner, Roessler & Hasslacher Chemical Co.; *Secretary,* John I. Tierney, 614 Investment Bldg., Washington, D. C.

DR. E. W. LINDSTROM, head of the genetics department of the Iowa State College at Ames, is sailing on August 5 for France to assist the directors of the European office of the International Education Board, particularly in their work in biology and agriculture. His address for the next twelve months will be: International Education Board, 20, rue de la Baume, Paris (8°), France.

PROFESSOR C. F. BAKER has resigned, to take effect in November, from the College of Agriculture at Los Baños, Laguna, P. I., with which institution he has been associated for many years. He expects to spend next year with one of the Pan-Pacific research committees on the South Sea survey and thereafter will make headquarters at the University of Hawaii with President David Crawford. Arrangements have been made to house his large collection of natural history material at the Bishop Museum.

PROFESSOR C. W. HOWARD, who for the past ten years has been working on the upbuilding of the silk industry of Southern China, is returning from Canton to this country as head of the department of biology at Wheaton College. A correspondent writes that beginning his work in the department of biology of the Canton Christian College, Professor Howard developed the work in sericulture to such an extent that the Chinese government established the Kwongtung Provincial Bureau for the Improvement of Sericulture under his directorship. In response to the urging of the government officials, he will retain his connection with this work, returning to Canton for the summers for the next few years.

DR. WILLIAM H. TALIAFERRO, professor of parasitology, and Drs. Lucy Graves Taliaferro and Frances A. Coventry, research associates in the department of hygiene and bacteriology of the University of Chicago, have returned from a three months' trip to Central America. Through the courtesy of the United Fruit Company they spent most of their time working on the serology and immunology of malaria and various intestinal worms at the hospital of the Tela Railroad Company, in Tela, Honduras. Dr. Taliaferro has been invited to the school of tropical medicine of the University of Porto Rico as visiting professor of parasitology during the winter quarter of 1928.

PROFESSOR A. S. HITCHCOCK, curator of the grass herbarium of the U. S. National Museum, left Washington on July 1 for two months' field work on the Pacific Coast, especially in the Olympic Mountains.

DR. W. O. RICHTMANN, professor of pharmacognosy at the University of Wisconsin and superintendent of the pharmaceutical garden of the Wisconsin Pharmaceutical Experiment Station, is abroad for a

three months' tour. His principal object is to consult the British Museum and other libraries in connection with his study of the history of American medicinal plants and drugs.

AT the Montana College and Experiment Station President A. Atkinson has been granted leave of absence for study during the next college year. Dean and Director F. B. Linfield has been appointed acting president in his absence. Dr. Arnold H. Johnson, assistant chemist in the station, has also been granted leave of absence for one year to accept a fellowship for study in Europe given by the International Education Board.

FORESTERS and chemists from England, Australia, Sweden, Finland and Mexico, detailed recently to the U. S. Forest Products Laboratory of the University of Wisconsin, constitute the largest group of foreign research men ever gathered at the federal laboratory at one time. Included in the foreign research group are Wilhelm Rosen and Eric Ostlin, of the Scandinavian-American Foundation; J. E. Cummins and H. S. Dadswell, of the Australian Council for Scientific and Industrial Research; W. G. Campbell, of the Commonwealth (British) Foundation; Hermenegildo Barrios, of Mexico, and Uno W. Lehtinen, of the Finnish State Forest Service.

DR. HARRISON R. HUNT, head of the department of zoology and geology at the Michigan State College, is making a lecture tour through the west in the interests of the American Eugenics Society. He planned to lecture on eugenics and human heredity at the University of Omaha, Oregon State Normal School, State Normal School at Bellingham, Washington, and the State Normal School at Ellensburg, Washington.

DR. JACK CECIL DRUMMOND, professor of biochemistry in University College, London, vice-dean of the faculty of medical science, is among those lecturing at the American Chemical Society Institute at the Pennsylvania State College.

THE death is announced on May 15 of Dr. Edwin B. Payson, professor of botany in the University of Wyoming.

UNIVERSITY AND EDUCATIONAL NOTES

YALE UNIVERSITY has received a bequest of more than $150,000 from the estate of General Charles H. Pine, formerly of Ansonia, which, together with a gift of General Pine's made in 1913, brings the Charles H. Pine scholarship fund at Yale to a total of more than $215,000.

AT the commencement exercises of the University of Maryland gifts were announced amounting to $150,000. The largest gift was from Captain Isaac E. Emerson, of Baltimore, who provided endowment for a professorship in the school of pharmacy and a fellowship in the school of medicine. The University of Maryland during the coming biennium will have almost $1,000,000 for new buildings and improvements from the state.

THE University of London has received two gifts of £10,000 each, one from an anonymous donor and one from Messrs. Wander, Ltd., for the establishment of a university chair of dietetics.

IT is announced at Columbia University that Dr. Durward R. Jones, recently epidemiologist of the State Department of Health of South Dakota, will succeed Dr. Alton S. Pope as assistant professor of epidemiology, and that Dr. Adelaide Ross Smith, recently physician to the New York State Industrial Board, will succeed Assistant Professor Frank G. Pedley as associate professor of medicine in industrial hygiene. Dr. Smith will be in charge of the industrial department at the Vanderbilt Clinic of the College of Physicians and Surgeons. Dr. Pope is now epidemiologist of the Chicago Health Department, and Dr. Pedley will assume charge of the new department of industrial medicine at McGill University Medical School on August 1.

ERIC PONDER, M.D., Sc.D., F.R.S., of Edinburgh, has been appointed associate professor of general physiology in New York University and will have charge of the courses in physiology in University College. He will also direct work in general physiology in the graduate school.

DR. HERBERT O. CALVERY, instructor in physiological chemistry at the Johns Hopkins Medical School, has been appointed assistant professor of physiological chemistry at the University of Michigan.

DR. D. A. WORCESTER has been appointed associate professor of educational psychology in the University of Nebraska.

DR. N. B. DREYER, assistant professor of physiology, Dalhousie University Faculty of Medicine, has resigned to accept an appointment in the department of pharmacology at McGill University Faculty of Medicine, Montreal.

DISCUSSION

MISUSE OF THE NAME "LEUCOSCOPE"

I ASK the privilege of your columns in order to clarify a somewhat confused account of some work

of mine given in Walsh's "Photometry,"[1] pp. 244–245. Since the same mistake has also been made by others heretofore and bids fair to become prevalent, it seems desirable to publish a correction. I do this not for the sake of finding fault, but to prevent in so far as possible, the continued spread of mistaken ideas in regard to the subject-matter in question. It is well known how errors once incorporated in a standard text are copied and recopied without limit.

The error in question is that the instrument designated by Mr. Walsh as "The Leucoscope" is *not* the leucoscope, but the "rotary dispersion colorimetric photometer." The pertinent facts are as follows:

(1) The leucoscope is an instrument, the invention of which is commonly attributed to Helmholtz, about 1870–80.[2] It consists essentially of a quartz plate between a *Wollaston* prism and a nicol prism through which the observer views *two* images of the *same source.*

(2) The instrument which Mr. Walsh describes, and calls "The Leucoscope" is properly called the "rotatory dispersion colorimetric photometer."[3] I particularly object to naming it "Priest's leucoscope" as is done in the index of Mr. Walsh's book. It is a special form of the Arons Chromoscope[4] and its embryonic form may be seen in Zoellner's colorimeter.[5] My connection with this instrument has been to develop the theory and practice of its use in the colorimetry and photometry of incandescent sources and daylight, and to design an instrument especially suited to these purposes.

(3) In principle, manner of use and specific purpose served, the two instruments are very different. About all that they have in common is the fact that they both contain nicol prisms and quartz plates and the circumstance that I have written papers dealing with each of them separately.

It seems unnecessary to use your space to set forth in detail the distinctions between these two instruments. All confusion may be removed by consulting my papers which deal, respectively, with the two different instruments.[6]

IRWIN G. PRIEST

[1] J. W. T. Walsh, "Photometry," Constable, London, 1926.

[2] There has been some slight controversy as to the relative contributions of Helmholtz, and one of his pupils, Diro Kitao, to the development of the instrument. Edm. Rose (1863) described an instrument which may be regarded as the prototype of the leucoscope. A review of the history of the instrument and a full bibliography have been published in my paper on the leucoscope, *Jour. Op. Soc. Am. 4,* pp. 448–495, 1920.

[3] *J. O. S. A. & R. S. I. 7,* folded insert facing p. 1199, December, 1923.

[4] Leo Arons, *Ann. der Phy.* (4) *39,* pp. 545–568, 1912.

[5] J. C. F. Zoellner, "Photometrie des Himmels," Berlin, 1861; G. Mueller, "Photometrie der Gestirne," pp. 244–254, Leipzig, 1897.

[6] "A New Study of the Leucoscope . . . ," *J. O. S. A. 4,* pp. 448–495, November, 1920; "Colorimetry and Photometry . . . by the Method of Rotatory Dispersion," *J. O. S. A. & R. S. I. 7,* pp. 1175–1209, December, 1923.

TADPOLES AS A SOURCE OF PROTOZOA FOR CLASSROOM USE

IN SCIENCE, Vol. 56, pp. 439–441, there appeared a note by Dr. R. W. Hegner on frog and toad tadpoles as sources of intestinal protozoa for teaching purposes. During the last four years the writer has examined hundreds of tadpoles for intestinal protozoa, and is able to state that he has frequently found most of the species listed by Hegner in his paper, viz., *Trichomonas augusta, Hexamitus intestinalis, Nyctotherus cordiformis, Opalina ranarum, Endamoeba ranarum,* and *Euglenamorpha hegneri,* the latter an Euglena-like flagellate with three flagella. *Giardia agilis* and *Balantidium entozoon* have never been observed by the writer. *Euglena spirogyra, Phacus* sp.? and several species of desmids and diatoms, which are normally free-living forms, are often present in large numbers in the rectum of tadpoles, in which habitat they appear to be little the worse for any contact they may have had with the digestive juices of their host.

In addition to the protozoa enumerated by Hegner several other species have been more or less frequently encountered. These are *Chilomastix caulleryi* Alexeieff 1909, *Mastigina hylae* (Frenzel 1892) Goldschmidt 1907, and *Endolimax ranarum* Epstein and Ilowaisky 1914.

Chilomastix caulleryi is a flagellate which lives in the rectum of the tadpoles of *Rana catesbiana* and *Rana clamata.* It sometimes occurs, in large numbers, but is likely to be overlooked among the more numerous representatives of the species *Trichomonas augusta.* Its morphology is practically identical with that of *Chilomastix mesnili* of man. Its larger size makes it more favorable for study than the human form.

Mastigina hylae is a large and extremely interesting protozoon which belongs to the flagellate family Rhizomastigidae. Its most striking features are the prominent anterior nucleus and the constant active streaming of the protoplasm filled with remnants of the green algae and protozoa upon which it has fed. The small anterior flagellum is inconspicuous and will be overlooked unless carefully searched for. The writer has never seen in any other cell protoplasmic streaming so vigorous and continuous as in this form. For a more detailed description of this species the reader is referred to a paper by the writer in the

Journal of Parasitology for June, 1925. This protozoon has been found in tadpoles of *Rana catesbiana* and *R. clamata* in New Jersey and in those of *R. pipiens* in Iowa.

Endolimax ranarum is a smaller amoeba than *Endamoeba ranarum*, and is much less frequently encountered. Its nucleus is more or less typical of that of other members of the genus and careful staining is required to bring it out.

On the basis of the combined experiences of Dr. Hegner and those of the writer, we may confidently expect to find in our American tadpoles most of the following species of intestinal protozoa: (1) *Opalina ranarum*, (2) *Nyctotherus cordiformis*, (3) *Balantidium entozoon* (not observed by either Hegner or the writer), (4) *Giardi agilis*, (5) *Trichomonas augusta*, (6) *Chilomastix caulleryi*, (7) *Hexamitus intestinalis*, (8) *Euglenamorpha hegneri*, (9) *Mastigina hylae*, (10) *Endamoeba ranarum*, and (11) *Endolimax ranarum*. *Trichomonas batrachorum* and *Polymastix bufonis* are two other species which have been found in frogs and should be searched for in tadpoles. This formidable list of intestinal protozoa makes tadpoles invaluable for teachers in protozoology and invertebrate zoology.

The writer wishes also to call the attention of bacteriologists and microbiologists to a rather unusual bacterial flora which is sometimes encountered in the rectum of the tadpole. Large spirilla with a prominent spore at each end, bacilli of a crescentic shape with a prominent spore at each end, and other equally remarkable forms have been seen by the writer while making examinations of the contents of the rectum of tadpoles.

ELERY R. BECKER

IOWA STATE COLLEGE

THE EFFECT OF ULTRAVIOLET RADIATIONS UPON SOY BEANS

A SERIES of experiments was performed to study the effect of ultraviolet radiations upon the subsequent development of the soy bean. The full spectrum of an air-cooled quartz mercury lamp was used in every case. The plants were kept under rigidly controlled conditions.

The first outstanding result noted was that the longer the exposure the shorter the plant, that is, in successive experiments as the length of exposure was increased the internodes of the plant became shorter. The stems were very brittle and the leaf tissue very stiff and rigid.

The internal changes were equally interesting. The stems of irradiated plants were approximately one and one half times as large in diameter as the control plants. There was also a reduction of the number of medullary rays in irradiated plants, so that these plants tend to show that the meristematic tissues remain active for a very much longer period of time than in the control plants. The cells of the medullary rays under ordinary conditions remain parenchymatous but in irradiated plants have gone further and developed into xylem and phloem. Furthermore, because of differential growth the stems became hollow.

A detailed report of the work will be prepared later. The author wishes to express her appreciation to Dr. W. J. G. Land and Dr. C. A. Shull for their kind help and inspiration.

H. REBECCA DANE

UNIVERSITY OF CHICAGO

FLORA OF BARRO COLORADO ISLAND, CANAL ZONE

RECENTLY there appeared in SCIENCE an account of Barro Colorado Island.[1] Visiting scientists working upon plants are concerned with the names of the species to be found on the island. All such workers will be interested in a list of plants of Barro Colorado Island that has just been issued by the Smithsonian Institution. The author, Mr. Paul C. Standley,[2] who spent a week on the island, has traveled extensively in Central America and has published several articles on the flora of these regions. The flora is an annotated list without keys or complete descriptions, but the accompanying notes on common names, uses and prominent characters will be a great aid to those taking advantage of the facilities of the laboratory on the island.

Mr. Standley has also published a paper on the ferns of the island.[3] A flora of the Canal Zone by the same author is now in press.

The bibliography of papers relating to Barro Colorado Island now includes over 50 titles.

A. S. HITCHCOCK

BUREAU OF PLANT INDUSTRY,
WASHINGTON, D. C.

A DAYLIGHT METEOR

AT a golf course on Warwick Neck, near Providence, Rhode Island, I was on a fairway overlooking Narragansett Bay about one o'clock in the afternoon of June 1, in brilliant sunlight when my companion and I distinctly saw what seemed to be a small meteorite dropping over the bay. It was fol-

[1] Kellogg, Vernon, "Barro Colorado Island Biological Station," SCIENCE 65: 535, 1927.

[2] Standley, Paul C., "The Flora of Barro Colorado Island, Panama," Smithsonian Miscellaneous Collections 78: No. 8, 1–32, 1927.

[3] Standley, Paul C., "The Ferns of Barro Colorado Island," *American Fern Journal* 16: 112–120, 1926; 17: 1–8, 1927.

lowed by a train of sparks much like a spent rocket, but originated too high to have been one. From our position we could not see if it reached the water. While it seemed to be only two or three miles away, I realized that such appearances are deceptive. There was no sound accompanying the fall audible from where we stood.

WILLIAM L. BRYANT

PARK MUSEUM

QUOTATIONS

THE NATIONAL MUSEUM OF AUSTRALIAN ZOOLOGY

IN 1924 the Federal Parliament of Australia, knowing the fact that the unique native fauna of the commonwealth was fast disappearing, and recognizing its importance to medical science, founded the National Museum of Australian Zoology. It was a wise and statesmanlike act, the full effect of which is only now beginning to be seen. Dr. Colin Mackenzie was appointed director, with the title of professor of comparative anatomy. It was a museum with a difference. In the previous year Professor Mackenzie had presented to the commonwealth his specimens of living native animals, together with the buildings and fencing on the Research Reservation at Healesville. He had given also his collection of macroscopic and microscopic specimens, numbering many thousands; and these now form the basis of the museum collection. Each specimen has a direct application to some medical or surgical problem. Nothing quite like the collection of normal histological preparations from reptiles, monotremes and marsupials, with which human or other mammalian tissue can be compared, exists anywhere in the world, and we are glad to know that illustrated atlases describing the collection are being prepared for publication—a huge enterprise which has been begun not a day too soon. Early in 1923, when commenting on the announcement that the commonwealth government had passed an act to establish a Museum of Australian Zoology, we observed that there was clearly an obligation on Australia to preserve a full series of specimens, since the whole indigenous fauna of Australia seemed only too likely to follow Tasmanian man to extinction. The commonwealth legislature has now gone rather further than we hoped, for it has not only allotted a site for the National Museum of Australian Zoology at Canberra, the new capital of Australia, but the Federal Capital Commission has provided a site for a zoological park or reservation, in which will be kept living specimens of Australian and Tasmanian native animals in their natural state. The area of the site for the museum, laboratories and lecture theater is about five and a half acres, in a magnificent situation on Action Hill, facing Parliament House. The research reservation or zoological park, containing about eighty acres, is on a peninsula bounded on two sides by the river Molonglo. The report of the Parliamentary Standing Committee on Public Works, dealing with the construction of buildings, has now been published, authorizing for this purpose a sum approximating £100,000. The report has received the unanimous approval of the Federal Parliament, and the buildings, representing what is really the first stage in the establishment of the National University of Australia, will be begun immediately. When the buildings are completed every facility will be offered to workers—not only Australian, but also from other countries—wishing to study comparative anatomy and its application to modern medical and surgical practice. The museum is now at Melbourne, but is to be moved to Canberra next year. To its original contents many important additions have recently been made, including the collection of specimens valued at £25,000 belonging to Dr. George Horne, of Melbourne, dealing with the Stone Age men of Australia, and also a collection of aboriginal skulls made by Dr. Arthur Nankivell, of Kerang. The museum also possesses the Froggatt entomological collection, and that of Mr. Murray Black dealing with the aborigines of South-East Victoria. The completely fossilized prehistoric Cohuna skull, together with many other specimens of anthropological value, belong to the museum. The federal government of Australia is to be congratulated on its decision to establish a center for the advancement of comparative anatomy, which admittedly is the foundation of all the medical sciences. We may venture to express the hope that the lead now given by Professor Colin Mackenzie will encourage wealthy Australians to display a similar national spirit, and by liberal endowments help on the necessary research work in the interests of humanity.—*The British Medical Journal.*

SCIENTIFIC BOOKS

The Internal Constitution of the Stars. By A. S. EDDINGTON, M.A., F.R.S., Cambridge; at the University Press, 1926. 407 pp., 5 figures.

THE fundamental problem in astrophysics may be regarded as the construction of models which, obeying the well-established laws of theoretical physics, describe the observed intrinsic properties of the stars. Thus there are stellar models which describe the formation of the observed spectra in reversing layer and chromosphere, models which describe the formation of binary stars by fission and the behavior of cepheid

variables and finally models which lead to relations between the mass, radius, luminosity and effective temperature of a star. Such stellar models, both as regards their field of usefulness in scientific thought as well as their frequent incompatibility with one another, are closely analogous to the various atomic models designed to describe the properties of matter. In astronomy, as well as in atomic physics, the value of a given model depends upon the range of facts *quantitatively* described, upon its powers of prediction and upon the small number of special postulates built into the model.

It is now some ten years since the appearance of Eddington's first paper on the interior of a star. The general theory therein developed and the model adopted furnished a successful description of the stars as then known. The development by Kramers, from the correspondence principle, of an expression for the mass coefficient of absorption permitted Eddington in 1924 greatly to improve his model and to predict the mass-luminosity relation. This prediction and its verification have profoundly modified astronomical conceptions of stellar evolution. At the same time, Eddington's theory has reacted upon modern atomic physics and has inspired numerous important investigations on the physics of matter at high temperatures, notably the work of Eggert (which led to Saha's important theory) and the recent investigations of R. H. Fowler. Astronomers and physicists both, then, will welcome the present volume in which Eddington gives a systematic development of the whole theory.

The general treatment may be outlined in the following manner: Given a mass of gas under its own gravitational attraction, the internal distribution of density, pressure and temperature may be derived from the equation of state of the gas and the requirements of mechanical and thermal equilibrium. The condition of mechanical equilibrium requires that the total pressure (gas pressure + radiation pressure) at any internal point balances the weight of the overlying layers, and is expressed by the well-known differential equation of hydrostatics. The condition of thermal equilibrium requires that the flow of heat does not disturb the internal distribution of temperature, but to formulate the differential equation it is necessary to know the mode of heat transfer. Schwarzschild has shown that this transfer in the outer layers of the sun is by radiation rather than convection, and Eddington has shown that convection currents can in fact be only maintained at the expense of their own mechanical energy and so must die out. Granting that heat transfer is by radiation, the well-known differential equation of radiative equilibrium may be derived from elementary considerations, and this equation, Eddington has shown, is accurate to a high order of approximation.

To integrate these differential equations, it is now necessary to make certain assumptions, or in other words to adopt a definite stellar model. Eddington assumes that the star consists of a perfect gas of constant molecular weight in which the product ηk is invariable throughout the interior. Here η is the ratio of the average liberation of energy per gram within any sphere of radius r to the average liberation of energy per gram in the whole star, and k is the mass-coefficient of absorption. On this model and without difficult quadratures it is possible to arrive at two important results—firstly, that the ratio of radiation pressure to gas pressure throughout the star is constant and a function of the stellar mass; and secondly, that *for stars of the same mass the luminosity varies inversely as* ηk. A detailed solution by quadratures, integrating from within outwards, as carried through first by Emden, gives the internal distribution of density, pressure and temperature, but involves as an unknown constant the mean molecular weight. The mean molecular weight of course depends upon the degree of ionization in the interior which in turn depends upon the temperature and pressure. A solution by trial and error indicates a molecular weight of 2.1 which is adopted for subsequent work. Accordingly when the model star is of the same mass and radius as our sun, its central density turns out to be 76 gms. per cu. cm. and its central temperature forty million degrees. Finally, Kramers' law of absorption is introduced, and this, by virtue of the constant proportionality throughout the model of the density to the cube of the temperature, reduces to the form that the absorption coefficient varies inversely as the square root of the temperature. Introducing this result into the relation italicized above the mass luminosity relation is reached—

$$\log(\text{Luminosity}) = \frac{7}{5}\log(\text{Mass}) + \frac{3}{2}\log\frac{\text{radiation pressure}}{\text{total pressure}} + \frac{4}{5}\log(\text{Surface temperature}) + \text{Const.}$$

absorption law), and this is fixed from the mass, luminosity and effective temperature of a single star (Capella). It is then found that all thirty-seven stars of known mass and luminosity, both giants and dwarfs, lie on Eddington's mass-luminosity curve.

Of the several quantitative predictions furnished by Eddington's model, none is more striking or more general than this relation that the luminosity of a star, apart from a small factor depending upon the surface temperature, is a single-valued function of its mass. The relation contains but one disposable constant (the proportionality constant of Kramers'

with an average residual of the order of half a magnitude. It is at first sight paradoxical that a "perfect gas" model should accurately predict the luminosity of dwarf stars with a mean density as high as that of copper. The paradox is, however, removed if Eddington's model be regarded as giving an acceptable picture of the actual interior of a star. In that event we must regard the stellar interior as being highly ionized so that the stellar "molecules" (free electrons and atoms ionized down to the *K* shell) have but one millionth the volume of terrestrial molecules. The equation of state for a perfect gas will therefore be applicable in the actual stellar interior at mean densities comparable with that of platinum. Moreover, we may qualitatively predict the possible existence of stars with mean densities for in excess of terrestrial experience—a prediction recently verified by the "white dwarfs" of which one, the companion of Sirius, has a mean density of sixty-one thousand grams per cubic centimeter. Quantitatively and qualitatively a veritable triumph for the Eddington model!

The model, as so far detailed, predicts that for stars of the same mass any surface temperature or spectral type is equally probable. The facts are, however, that the stars fall into a Russell diagram which must now be described as a reversed figure Z consisting of three branches—the giant, main sequence and white dwarf branch. Along the main sequence, which contains by far the greatest number of stars, there is a very definite relation between spectral type, on the one hand, and mass, or equivalent luminosity, on the other. Eddington's model will only obey a relation of this kind if the liberation of energy per gram rapidly decreases from star to star down the main sequence. We are, therefore, forced to postulate an unknown source of energy, and one of the most interesting and stimulating chapters in the book under review is concerned with a very full discussion of the nature of this source and the cause of its variation. A survey of the possible sources, from the viewpoint of the time-scale demanded by both geologists and astronomers, indicates that some form of subatomic energy is required. The difficulty on Eddington's model, however, is that the temperatures which stimulate and control this subatomic source are absurdly low. It would seem as if the only subatomic source compatible both with contemporary physics and Eddington's model is C. T. R. Wilson's "runaway electron," a not very encouraging prospect. A question of interest to the astronomer is whether the source or sources form a large fraction of the mass of the star. It is only in this event that any important evolution, which can only result from a loss of mass, is possible in the life history of the star. Quite apart from any stellar model, and accepting the mass-luminosity law as a purely empirical relation, Trumpler's recent observations of the coexistence in open, and presumably old, clusters of massive stars of types B, F, G, coeval with ordinary dwarfs of types F and G, seem to preclude the possibility of such evolution in these clusters. Eddington says, "it seems almost necessary to throw over the idea of any important advance in evolution in the life-time of the clusters, and it then becomes a question whether there is any point in retaining the idea for stars in general"—a statement which should commend itself to the conservative astronomer.

The general plan of the book, which discusses these and many other problems, is firstly to lay the foundations of thermodynamics and the quantum theory and then to proceed step by step in, roughly speaking, an historical order, through the whole theory. In this way are discussed in successive chapters Emden's quadratures of the differential equations for various polytropes, the derivation of the equation of radiative equilibrium, the solution of the equations with a detailed justification of the various assumptions included in the model, the mass-luminosity law and the problem of Cepheid and other variable stars. Chapter IX deals with the coefficient of opacity, and here Eddington's model encounters its second principal difficulty, the other difficulty, of course, having to do with sources of energy. Kramers' theory gives the following expression for the mass coefficient of absorption:

$$\log(K) = \log(\text{Density}) - \log(\text{Molecular Weight}) - \frac{7}{2}\log(\text{Temperature}) + \text{Constant}.$$

The numerical value of the constant is predicted by theory and satisfactorily verified by laboratory experiments with X-rays. This is the same constant, however, which was disposable in Eddington's model, and for which an astronomical value was obtained. The astronomical value exceeds the theoretical one, verified by terrestrial experiment, by a factor of ten. Eddington's thorough discussion of the whole problem reveals no adequate explanation of this discrepancy. Subsequent chapters discuss ionization and diffusion in the star, sources of energy, models for the outside of the star (largely due to Milne) and finally diffuse matter in space. Special mention should be made of the treatment of diffusion and von Zeipel's general theorem on a rotating star. If these theories which are applicable to all models can be successfully defended they rule out of court models, such as those recently proposed by Jeans, in which there is a concentration towards the stellar center of the heavier elements.

The book is written with Eddington's characteris-

tic clarity and abounds in happy and stimulating allusions. It can not fail to suggest to every serious reader numerous subjects for further observational and theoretical investigation. In future editions the value of the book would be enhanced for the reviewer, and possibly also for other observational astronomers of slender mathematical attainments, by the interpolation of a chapter between III and IV giving a brief and as nearly as possible self-contained mathematical development of the whole theory. Reference could then be made forward from this chapter to the subsequent chapters, which would retain much their present form, for a detailed discussion of the various assumptions, for the quadrature of the differential equations, for the discussion of the opacity law and so on. I do not believe that such an interpolation would seriously interfere with the logical treatment of the theory, and it is conceivable that it might eliminate some of the many cross references, forwards and backwards, which are essential with the present arrangement.

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ARTIFICIAL TRANSMUTATION OF THE GENE

MOST modern geneticists will agree that gene mutations form the chief basis of organic evolution, and therefore of most of the complexities of living things. Unfortunately for the geneticists, however, the study of these mutations, and, through them, of the genes themselves, has heretofore been very seriously hampered by the extreme infrequency of their occurrence under ordinary conditions, and by the general unsuccessfulness of attempts to modify decidedly, and in a sure and detectable way, this sluggish "natural" mutation rate. Modification of the innate nature of organisms, for more directly utilitarian purposes, has of course been subject to these same restrictions, and the practical breeder has hence been compelled to remain content with the mere making of recombinations of the material already at hand, providentially supplemented, on rare and isolated occasions, by an unexpected mutational windfall. To these circumstances are due the wide-spread desire on the part of biologists to gain some measure of control over the hereditary changes within the genes.

It has been repeatedly reported that germinal changes, presumably mutational, could be induced by X or radium rays, but, as in the case of the similar published claims involving other agents (alcohol, lead, antibodies, etc.), the work has been done in such a way that the meaning of the data, as analyzed from a modern genetic standpoint, has been highly disputatious at best; moreover, what were apparently the clearest cases have given negative or contrary results on repetition. Nevertheless, on theoretical grounds, it has appeared to the present writer that radiations of short wave length should be especially promising for the production of mutational changes, and for this and other reasons a series of experiments concerned with this problem has been undertaken during the past year on the fruit fly, *Drosophila melanogaster*, in an attempt to provide critical data. The well-known favorableness of this species for genetic study, and the special methods evolved during the writer's eight years' intensive work on its mutation rate (including the work on temperature, to be referred to later), have finally made possible the finding of some decisive effects, consequent upon the application of X-rays. The effects here referred to are truly mutational, and not to be confused with the well-known effects of X-rays upon the distribution of the chromatin, expressed by non-disjunction, non-inherited crossover modifications, etc. In the present condensed digest of the work, only the broad facts and conclusions therefrom, and some of the problems raised, can be presented, without any details of the genetic methods employed, or of the individual results obtained.

It has been found quite conclusively that treatment of the sperm with relatively heavy doses of X-rays induces the occurrence of true "gene mutations" in a high proportion of the treated germ cells. Several hundred mutants have been obtained in this way in a short time and considerably more than a hundred of the mutant genes have been followed through three four or more generations. They are (nearly all of them, at any rate) stable in their inheritance, and most of them behave in the manner typical of the Mendelian chromosomal mutant genes found in organisms generally. The nature of the crosses was such as to be much more favorable for the detection of mutations in the X-chromosomes than in the other chromosomes, so that most of the mutant genes dealt with were sex-linked; there was, however, ample proof that mutations were occurring similarly throughout the chromatin. When the heaviest treatment was given to the sperm, about a seventh of the offspring that hatched from them and bred contained individually detectable mutations in their treated X-chromosome. Since the X forms about one fourth of the haploid chromatin, then, if we assume an equal rate of mutation in all the chromosomes (per unit of their length), it follows that almost "every other one" of the sperm cells capable of producing a fertile adult contains an "individually detectable" mutation in some chromosome or other. Thousands of untreated parent flies were bred as controls in the same way as the treated

ones. Comparison of the mutation rates under the two sets of conditions showed that the heavy treatment had caused a rise of about fifteen thousand per cent. in the mutation rate over that in the untreated germ cells.

Regarding the types of mutations produced, it was found that, as was to have been expected both on theoretical grounds and on the basis of the previous mutation studies of Altenburg and the writer, the lethals (recessive for the lethal effect, though some were dominant for visible effects) greatly outnumbered the non-lethals producing a visible morphological abnormality. There were some "semi-lethals" also (defining these as mutants having a viability ordinarily between about 0.5 per cent. and 10 per cent. of the normal), but, fortunately for the use of lethals as an index of mutation rate, these were not nearly so numerous as the lethals. The elusive class of "invisible" mutations that caused an even lesser reduction of viability, not readily confusable with lethals, appeared larger than that of the semi-lethals, but they were not subjected to study. In addition, it was also possible to obtain evidence in these experiments for the first time, of the occurrence of dominant lethal genetic changes, both in the X and in the other chromosomes. Since the zygotes receiving these never developed to maturity, such lethals could not be detected individually, but their number was so great that through egg counts and effects on the sex ratio evidence could be obtained of them *en masse*. It was found that their numbers are of the same order of magnitude as those of the recessive lethals. The "partial sterility" of treated males is, to an appreciable extent at least, caused by these dominant lethals. Another abundant class of mutations not previously recognized was found to be those which, when heterozygons, cause sterility but produce no detectable change in appearance; these too occur in numbers rather similar to those of the recessive lethals, and they may hereafter afford one of the readiest indices of the general mutation rate, when this is high. The sterility thus caused, occurring as it does in the offspring of the treated individuals, is of course a separate phenomenon from the "partial sterility" of the treated individuals themselves, caused by the dominant lethals.

In the statement that the proportion of "individually detectable mutations" was about one seventh for the X, and therefore nearly one half for all the chromatin, only the recessive lethals and semi-lethals and the "visible" mutants were referred to. If the dominant lethals, the dominant and recessive sterility genes and the "invisible" genes that merely reduce (or otherwise affect) viability or fertility had been taken into account, the percentage of mutants given would have been far higher, and it is accordingly evident that in reality the great majority of the treated sperm cells contained mutations of some kind or other. It appears that the rate of gene mutation after X-ray treatment is high enough, in proportion to the total number of genes, so that it will be practicable to study it even in the case of individual loci, in an attack on problems of allelomorphism, etc.

Returning to a consideration of the induced mutations that produced visible effects, it is to be noted that the conditions of the present experiment allowed the detection of many which approached or overlapped the normal type to such an extent that ordinarily they would have escaped observation, and definite evidence was thus obtained of the relatively high frequency of such changes here, as compared with the more conspicuous ones. The belief has several times been expressed in the *Drosophila* literature that this holds true in the case of "natural" mutations in this organism, but it has been founded only on "general impressions"; Baur, however, has demonstrated the truth of it in *Antirrhinum*. On the whole, the visible mutations caused by raying were found to be similar, in their general characteristics, to those previously detected in non-rayed material in the extensive observations on visible mutations in *Drosophila* carried out by Bridges and others. A considerable proportion of the induced visible mutations were, it is true, in loci in which mutation apparently had never been observed before, and some of these involved morphological effects of a sort not exactly like any seen previously (*e.g.*, "splotched wing," "sex-combless," etc.), but, on the other hand, there were also numerous repetitions of mutations previously known. In fact, the majority of the well-known mutations in the X-chromosome of *Drosophila melanogaster*, such as "white eye," "miniature wing," "forked bristles," etc., were reobtained, some of them several times. Among the visible mutations found, the great majority were recessive, yet there was a considerable "sprinkling" of dominants, just as in other work. All in all, then, there can be no doubt that many, at least, of the changes produced by X-rays are of just the same kind as the "gene mutations" which are obtained, with so much greater rarity, without such treatment, and which we believe furnish the building blocks of evolution.

In addition to the gene mutations, it was found that there is also caused by X-ray treatment a high proportion of rearrangements in the linear order of the genes. This was evidenced in general by the frequent inherited disturbances in crossover frequency (at least 3 per cent. were detected in the X-chromosome alone, many accompanied but some unaccompanied by lethal effects), and evidenced specifically by various cases that were proved in other ways to involve inversions,

"deficiencies," fragmentations, translocations, etc., of portions of a chromosome. These cases are making possible attacks on a number of genetic problems otherwise difficult of approach.

The transmuting action of X-rays on the genes is not confined to the sperm cells, for treatment of the unfertilized females causes mutations about as readily as treatment of the males. The effect is produced both on oöcytes and early oögonia. It should be noted especially that, as in mammals, X-rays (in the doses used) cause a period of extreme infertility, which commences soon after treatment and later is partially recovered from. It can be stated positively that the return of fertility does not mean that the new crop of eggs is unaffected, for these, like those mature eggs that managed to survive, were found in the present experiments to contain a high proportion of mutant genes (chiefly lethals, as usual). The practice, common in current X-ray therapy, of giving treatments that do not certainly result in permanent sterilization, has been defended chiefly on the ground of a purely theoretical conception that eggs produced after the return of fertility must necessarily represent "uninjured" tissue. As this presumption is hereby demonstrated to be faulty it would seem incumbent for medical practice to be modified accordingly, at least until genetically sound experimentation upon mammals can be shown to yield results of a decisively negative character. Such work upon mammals would involve a highly elaborate undertaking, as compared with the above experiments on flies.

From the standpoint of biological theory, the chief interest of the present experiments lies in their bearing on the problems of the composition and behavior of chromosomes and genes. Through special genetic methods it has been possible to obtain some information concerning the manner of distribution of the transmuted genes amongst the cells of the first and later zygote generations following treatment. It is found that the mutation does not usually involve a permanent alteration of all of the gene substance present at a given chromosome locus at the time of treatment, but either affects in this way only a portion of that substance, or else occurs subsequently, as an after-effect, in only one of two or more descendant genes derived from the treated gene. An extensive series of experiments, now in project, will be necessary for deciding conclusively between these two possibilities, but such evidence as is already at hand speaks rather in favor of the former. This would imply a somewhat compound structure for the gene (or chromosome as a whole) in the sperm cell. On the other hand, the mutated tissue is distributed in a manner that seems inconsistent with a general applicability of the theory of "gene elements" first suggested by Anderson in connection with variegated pericarp in maize, then taken up by Eyster, and recently reenforced by Demerec in *Drosophila virilis*.

A precociously doubled (or further multiplied) condition of the chromosomes (in "preparation" for later mitoses) is all that is necessary to account for the above-mentioned *fractional effect* of X-rays on a given locus; but the theory of a divided condition of each gene, into a number of (originally identical) "elements" that can become separated somewhat indeterminately at mitosis, would lead to expectations different from the results that have been obtained in the present work. It should, on that theory, often have been found here, as in the variegated corn and the eversporting races of *D. virilis*, that mutated tissue gives rise to normal by frequent "reverse mutation"; moreover, treated tissues not at first showing a mutation might frequently give rise to one, through a "sorting out" of diverse elements, several generations after treatment. Neither of these effects was found. As has been mentioned, the mutants were found to be stable through several generations, in the great majority of cases at least. Hundreds of non-mutated descendants of treated germ cells, also, were carried through several generations, without evidence appearing of the production of mutations in generations subsequent to the first. Larger numbers will be desirable here, however, and further experiments of a different type have also been planned in the attack on this problem of gene structure, which probably can be answered definitely.

Certain of the above points which have already been determined, especially that of the fractional effect of X-rays, taken in conjunction with that of the production of dominant lethals, seem to give a clue to the especially destructive action of X-rays on tissues in which, as in cancer, embryonic and epidermal tissues, the cells undergo repeated divisions (though the operation of additional factors, *e.g.*, abnormal mitoses, tending towards the same result, is not thereby precluded); moreover, the converse effect of X-rays, in occasionally producing cancer, may also be associated with their action in producing mutations. It would be premature, however, at this time to consider in detail the various X-ray effects previously considered as "physiological," which may now receive a possible interpretation in terms of the gene-transmuting property of X-rays; we may more appropriately confine ourselves here to matters which can more strictly be demonstrated to be genetic.

Further facts concerning the nature of the gene may emerge from a study of the comparative effects of varied dosages of X-rays, and of X-rays administered at different points in the life cycle and under varied conditions. In the experiments herein re-

ported, several different dosages were made use of, and while the figures are not yet quite conclusive they make it probable that, within the limits used, the number of recessive lethals does not vary directly with the X-ray energy absorbed, but more nearly with the square root of the latter. Should this lack of exact proportionality be confirmed, then, as Dr. Irving Langmuir has pointed out to me, we should have to conclude that these mutations are not caused directly by single quanta of X-ray energy that happen to be absorbed at some critical spot. If the transmuting effect were thus relatively indirect there would be a greater likelihood of its being influenceable by other physico-chemical agencies as well, but our problems would tend to become more complicated. There is, however, some danger in using the total of lethal mutations produced by X-rays as an index of gene mutations occurring in single loci, for some lethals, involving changes in crossover frequency, are probably associated with rearrangements of chromosome regions, and such changes would be much less likely than "point mutations" to depend on single quanta. A reexamination of the effect of different dosages must therefore be carried out, in which the different types of mutations are clearly distinguished from one another. When this question is settled, for a wide range of dosages and developmental stages, we shall also be in a position to decide whether or not the minute amounts of gamma radiation present in nature cause the ordinary mutations which occur in wild and in cultivated organisms in the absence of artificially administered X-ray treatment.

As a beginning in the study of the effect of varying other conditions, upon the frequency of the mutations produced by X-rays, a comparison has been made between the mutation frequencies following the raying of sperm in the male and in the female receptacles, and from germ cells that were in different portions of the male genital system at the time of raying. No decisive differences have been observed. It is found, in addition, that aging the sperm after treatment, before fertilization, causes no noticeable alteration in the frequency of detectable mutations. Therefore the death rate of the mutant sperm is no higher than that of the unaffected ones; moreover, the mutations can not be regarded as secondary effects of any semi-lethal physiological changes which might be supposed to have occurred more intensely in some ("more highly susceptible") spermatozoa than in others.

Despite the "negative results" just mentioned, however, it is already certain that differences in X-ray influences, by themselves, are not sufficient to account for all variations in mutation frequency, for the present X-ray work comes on the heels of the determination of mutation rate being dependent upon temperature (work as yet unpublished). This relation had first been made probable by work of Altenburg and the writer in 1918, but was not finally established until the completion of some experiments in 1926. These gave the first definite evidence that gene mutation may be to any extent controllable, but the magnitude of the heat effect, being similar to that found for chemical reactions in general, is too small, in connection with the almost imperceptible "natural" mutation rate, for it, by itself, to provide a powerful tool in the mutation study. The result, however, is enough to indicate that various factors besides X-rays probably do affect the composition of the gene, and that the measurement of their effects, at least when in combination with X-rays, will be practicable. Thus we may hope that problems of the composition and behavior of the gene can shortly be approached from various new angles, and new handles found for their investigation, so that it will be legitimate to speak of the subject of "gene physiology," at least, if not of gene physics and chemistry.

In conclusion, the attention of those working along classical genetic lines may be drawn to the opportunity, afforded them by the use of X-rays, of creating in their chosen organisms a series of artificial races for use in the study of genetic and "phaenogenetic" phenomena. If, as seems likely on general considerations, the effect is common to most organisms, it should be possible to produce, "to order," enough mutations to furnish respectable genetic maps, in their selected species, and, by the use of the mapped genes, to analyze the aberrant chromosome phenomena simultaneously obtained. Similarly, for the practical breeder, it is hoped that the method will ultimately prove useful. The time is not ripe to discuss here such possibilities with reference to the human species.

The writer takes pleasure in acknowledging his sincere appreciation of the cooperation of Dr. Dalton Richardson, Roentgenologist, of Austin, Texas, in the work of administering the X-ray treatments.

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SCIENTIFIC APPARATUS AND LABORATORY METHODS

AN INSTRUMENT FOR REPEATED DETERMINATIONS OF BLOOD VISCOSITY IN AN ANIMAL[1]

IN experiments where it is desirable to make repeated determinations of the viscosity of the blood of an animal, the withdrawal of the amount of blood

[1] From the Physiological Laboratories of the University of Chicago and the University of Western Ontario, London, Canada.

for the determinations and its replacement by fluid of less viscosity from the tissues causes a progressive diminution in the viscosity of the blood.

In order to make viscosity determinations without withdrawal of blood from the animal, the instrument to be described here was constructed.

DESCRIPTION OF THE INSTRUMENT

Figure (1) shows a semi-diagrammatic representa-

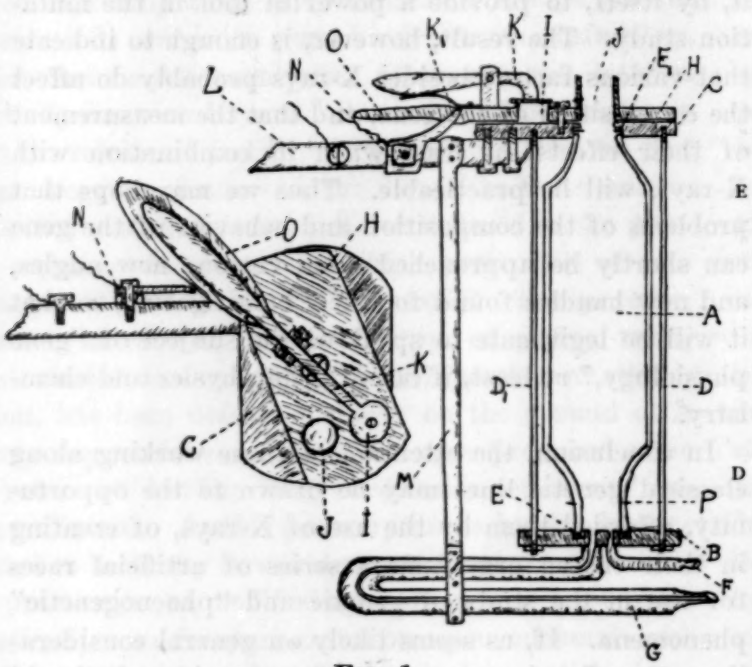

FIG. 1

tion of the instrument; "A" is a glass bulb of approximately 10 c.c. capacity and is clamped between two metal plates "B" and "C" by means of rods "D" and "D_1". Two rubber washers "E" and "E_1" placed between the ends of the glass bulb and the metal plates insure a tight joint. Leading from the lower end of the bulb through the metal plate "B" are two openings, the one leading into an arterial cannula "F" and the other into a glass tube "G" of fine capillary bore and shaped at the free end to facilitate tieing into a vein. A hole continuous with that of the upper end of the bulb passes through the upper plate. Above the upper plate "C" is a similar plate "H" held in place by a central screw and capable of being rotated upon plate "C." The movable plate has two openings "I" and "J"; by rotating the movable plate on the stationary one, one or the other of the openings is placed over the hole in the stationary plate leading into the upper end of the glass bulb. One of the openings in the movable plate is connected to a rubber tube through which a definite pressure equal to that in the arterioles of the animal can be applied. The pressure is supplied from the air line and regulated by means of a mercury valve. The other opening in the movable plate is fitted with a release valve "K" with spring "K_1" so that air may be allowed to escape from the bulb as it is being filled with blood; a small handle "O" is fastened to the moving plate to facilitate rotating it in bringing either opening over the upper end of the glass bulb. A rod "L" to clamp the instrument in place is attached to the upper stationary plate and from this a support "M" passes down to the capillary tube "G." An insulated terminal "N" with a projecting arm is attached to the supporting rod, so that a platinum point on the end of the arm just comes in contact with a similar point on the handle of the rotating plate when the hole connected with the air line is directly over the upper opening of the glass bulb. This insulated terminal and the frame of the instrument is connected in series with a dry cell and a signal magnet. A time clock is made to write on the drum above the signal magnet.

METHOD OF USE

After anesthetizing the animal and injecting sufficient heparin to make the blood incoagulable, the carotid artery and external jugular vein are exposed. The arterial cannula is then inserted into the artery on which a bull dog is placed and the vein prepared for insertion of the capillary tube. After opening the release valve "K" and having the revolving plate in position so that this opening is directly over the upper end of the glass bulb, the bull dog is removed from the artery and the blood allowed to displace the air in the bulb upward until the latter is completely filled with blood, the release valve is then closed. With the blood filling the glass bulb and the capillary tube, the free end of the latter is tied into the external jugular vein. The pressure with which the blood enters the bulb "A" is sufficient to insure its circulation in all parts of the bulb, after which it returns to the external jugular vein by way of the capillary tube "G." A determination may now be taken at any time.

Viscosity determinations are carried out as follows: The bull dog is first replaced on the artery and then the movable plate is quickly rotated by means of the handle "O" until the tube carrying the air pressure is directly over the upper opening in the glass bulb; thus a pressure equal to that in the arterioles is exerted upon the blood and it is forced out of the bulb into the venous side of the circulation. When the blood reaches the mark "P" on the lower neck of the bulb, the rotating plate is quickly moved back to its former position, the release valve "K" is opened and the clamp again removed from the artery. This allows the bulb to again fill with blood and the latter to circulate through the instrument. During the time the blood is being driven out of the bulb by means of air pressure, the arm of the

insulated terminal "N" is in contact with the metal handle of the movable plate; this makes an electrical contact and the signal magnet records the time taken for the blood to be driven through the capillary tube under a known pressure. This time when compared with that required for water under the same pressure gives the relative viscosity of the blood.

It is evident that any number of determinations may be taken without decreasing the amount of blood in the animal. The electrical recording of the time is of advantage in reducing the error due to the reaction time of the experimenter. Because of the short time the blood for determinations remains in the bulb, a bath for temperature control is not thought necessary.

In order to test the accuracy of the instrument, a series of experiments was carried out in which the relative viscosity of 7 per cent. gum arabic was determined by means of this instrument and the same procedure carried out with the Oswald viscosity pipette, water being taken as unity; in thirty determinations with each instrument it was found that the relative viscosity of the gum solution when determined with this instrument was 3.76 while with the Oswald type it was 3.78. These results appear to be well within the range of experimental error. The determinations were made at room temperature and the pressure on the fluid maintained at 70 mm. Hg.

The author is indebted to Professor A. J. Carlson for his helpful suggestions and criticisms of this work and to Mr. F. W. Claassens for his cooperation in construction of the instrument.

RUSSELL A. WAUD

SPECIAL ARTICLES

BALANTIDIA FROM PIGS AND GUINEA-PIGS: THEIR VIABILITY, CYST PRODUCTION AND CULTIVATION

THE following data concerning *Balantidium* occurring in the pig and guinea-pig are deemed of sufficient importance to warrant a report at this time. An abundance of material from the pig has been obtained from two packing plants within several squares of the laboratory, and Dr. W. R. Stokes, of the Baltimore City Health Department, has kindly furnished guinea-pigs for autopsy that died as a result of experimental work. Thus far of the twenty examined, 55 per cent. were infected with *Balantidium*. A colony of rhesus monkeys which also harbor *Balantidium* is maintained by Dr. Carl Hartman, of the Carnegie Institution. This article is a progress report on a problem of host-parasite relations which was suggested to me by Dr. R. W. Hegner.

VIABILITY

According to McDonald[1] (1922) the trophozoites of *Balantidium* of the pig become spherical when the intestinal contents are cooled to room temperature. McDonald also states that they live at room temperature not longer than eight hours. Accordingly, a thermos bottle was used to carry the material to the laboratory from the packing plant. No appreciable rounding was noted when the organisms were examined at room temperature. Therefore, the content of a bottle obtained January 3, 1927, was allowed to cool. Active, apparently normal, trophozoites were found in a sample taken from this bottle the next morning and on every subsequent morning until January 14. The relative numbers did not appear to diminish for about seven days, but then fell off very rapidly. The temperature of the contents of the bottle was taken after fourteen hours, and found to be 20° C. On several other occasions the organisms lived at room temperature for four days and on one occasion for seven days. The viability of trophozoites is also indicated by the fact that water from the trucks in which the pigs were transported from the cars was found to contain them; they remained perfectly normal in appearance at room temperature for twenty-four hours. Feces passed at least two hours previously by ten different pigs were collected from the pens at the packing plant. Trophozoites were found in seven of the ten samples. The pigs had been long in transit from Ohio and the feces were well formed so that they had to be torn apart in water before the trophozoites were freed. The latter appeared perfectly normal and swam about actively.

INFECTIVITY OF TROPHOZOITES

It seems to be the general opinion that ingestion of cysts must occur to set up an infection. (Fantham, Stephens and Theobald,[2] 1916); but Hegner[3] (1926) injected trophozoites from the pig into the stomach of the guinea-pig, and, when the animal was killed one hour later, active, apparently normal trophozoites were found in the stomach, small intestine and cecum. This experiment has been repeated with success.

[1] McDonald, J. D. 1922. "On *Balantidium coli* (Malmsten) and *Balantidium suis* (sp. nov.) with an Account of their Neuromotor Apparatus. Univ. Calif. Pub. Zool., 20: 243–300.

[2] Fantham, H. B., Stephens, M. D., and Theobald, M. A. 1916. "The Animal Parasites of Man," 900 pp. New York.

[3] Hegner, R. W. 1927. "Host-Parasite Relations between Man and His Intestinal Protozoa." The Century Co., New York. (In press.)

Trophozoites of the pig *Balantidium,* grown in culture, were injected into the stomach of a guinea-pig four weeks old. It died during the night, but after eighteen hours trophozoites, gorged with starch grains, were found in the esophagus and cecum. That these were not inhabitants of the intestine before the experiment began is indicated by the fact that the latter are always translucent and move slowly, whereas those from cultures are blackened from ingested starch and move actively. Later another guinea-pig from the same litter was given trophozoites by stomach tube direct from the pig. This animal also died during the night and trophozoites were found the next morning in the ileum, jejunum and cecum. They were of two kinds in the cecum; (1) those that parasitize the guinea-pig and (2) the starch-filled forms of the pig. When it is considered that trophozoites may live in feces for ten days at room temperature it is probable that they may serve as well as cysts in transmitting infection.

CYST PRODUCTION IN THE PIG

McDonald (1922) states that trophozoites were in various stages of encystment in the lower colon and rectum of the pig and all encysted in the formed feces. In Baltimore during February and March no cysts were found until about thirty pigs, all of which were infected with *Balantidium,* had been examined. They were not numerous; about three hours were required to pick out twenty specimens. Because of their large size, cysts of *Balantidium* can be distinguished with a binocular microscope. Material can be diluted in a Syracuse watch glass and examined much more rapidly than when slides are used. Cysts can be picked out with a micropipette and studied under the compound microscope. In this work, as well as by McDonald (1922), the cysts were found to be very resistant to fixing and staining. The nucleus and other structures are not revealed when they are treated with iodine eosine or even when Mallory's haematoxylin is run under the cover glass after fixation with Schaudinn's fluid. When bodies resembling cysts were finally found the material was treated in bulk with hot Schaudinn's and stained with iron haematoxylin (method of Kofoid and Swezy). They were then picked out and positively identified. Walker[4] (1913) and others state that fecal diagnosis for *Balantidium* in man and monkeys is unsatisfactory, because for long periods no cysts are passed. Walker (1913) states, as does McDonald (1922), that cysts are frequent in feces of pigs. Walker and others express the opinion that for this reason infection in man is usually contracted from pigs. Data obtained in Baltimore, however, indicate that cysts may be as scanty in pigs as in man, monkeys and guinea-pigs.

CULTIVATION

Much experimental work has been done recently and is being continued on cultivating parasitic protozoa. The first media tried by myself were made according to directions given by Dobell and Laidlaw[5] (1926) for *Endamoeba histolytica.* On one occasion trophozoites lived seventy-two hours and multiplied. The medium consisted of an inspissated human serum slant plus a fluid of Ringer's solution without dextrose, nine parts, and human serum, one part. Sterile rice starch was added. Transplants from this culture failed. Various egg media were tried with negative results. Walker (1913) concluded, as a result of experiments, that a 0.5 per cent. NaCl solution is best suited for *Balantidium.* Barret and Yarbrough[6] (1921) cultivated *Balantidium coli* successfully in a medium 0.5 per cent. NaCl, fifteen parts, plus human serum, one part. Their cultures were maintained thirty-two days. In order to ascertain whether Walker's data could be applied in the cultivation of *Balantidium* from the pig the concentration of the medium in which the organism lives was determined. Feces from the cecum were filtered through filter paper and the freezing point method employed, with a Beckmann thermometer. The reading of filtrate from fresh feces was minus 0.70° C.; of filtrate from feces kept forty-eight hours in the laboratory minus 0.79° C.; and of feces kept 168 hours it was minus 0.72° C. The freezing point of blood serum is about minus 0.6° C., and is isotonic with an 0.85 per cent. NaCl solution. Walker found this hypertonic for *Balantidium,* and preliminary trials carried out here seemed to confirm this conclusion. Hence it was thought that the hypertonicity of 0.85 per cent. NaCl is due to an excess of inorganic ions. Accordingly, 10 cc of each of the above fecal filtrates were evaporated to dryness; and the organic matter driven off by heating. The residue was taken up in 10 cc of distilled water and the freezing point found to be minus 0.17° C. This is isotonic with a NaCl solution of about 0.25 per cent. On the basis of the above data an attempt was made to prepare synthetic media,

[4] Walker, E. L. 1913. "Quantitative Determination of the Balantidicidal Activity of Certain Drugs and Chemicals as a Basis for Treatment of Infections with *Balantidium coli.*" *Philippine Journ. Sci.* (B), 8: 1–15.

[5] Dobell, C., and Laidlaw, P. P. 1926. "On the Cultivation of *Endamoeba histolytica* and Some Other Entozoic Amoebae." *Parasit.,* 18: 283–318.

[6] Barret, H. P., and Yarbrough, N. 1921. "A Method for Cultivation of *Balantidium coli,*" *Amer. Journ. Trop. Med.,* 1: 161.

using 0.25 per cent. NaCl solution and adding urea in one instance and aminoids, Biuret free, in another, to make the solution about isotonic with blood serum. Blood serum and starch were also added to some of the tubes. The results of culture experiments were invariably negative in the urea tubes. Growth was occasionally noted in the aminoids, but transplants were unsuccessful.

Successful results were finally secured by using the method of Barret and Yarbrough (1921) with a modified Ringer's solution instead of 0.5 per cent. NaCl. The latter contained: NaCl 6.5 gms., KCl 0.14 gms., $CaCl_2$ 0.12 gms., $NaHCO_3$ 0.20 gms., Na_2HPO_4 0.01 gms., per liter of distilled water. The ingredients were weighed from C. P. crystals on an analytical balance but no attempt was made to desiccate them before weighing. The freezing points of various solutions thus far used have ranged from minus 0.52° C. to minus 0.58° C. Eighteen cc is pipetted into clean test tubes and autoclaved. Two cc of human or horse serum is then added, plus a sprinkle of sterile rice starch. Pig serum has thus far proved unsatisfactory. A solution made from Loeffler's dehydrated blood serum is used frequently instead of the human or horse serum. This product is manufactured by the Digestive Ferments Company, of Detroit, Mich. The contents are listed as beef blood 3 parts and dextrose broth 1 part. Solution is obtained by adding 8 gms. of the powder to 100 cc of distilled water at 40° C. It is advantageous to measure the water in a 250 cc flask containing a few glass beads and sterilize. Shaking the flask with the beads aids in securing solution, but even so there is much suspended matter. A culture of *Balantidium* from the pig was maintained for fifty-four days and was still thriving on April 4. The tubes are kept in an incubator at 36° C. and transplants are made according to Barret and Yarbrough's technique. Twenty transplants have been made. They are made usually at three-day intervals, but on one occasion (7th transplant), a seven-day interval occurred. Trophozoites in abundance have been found on a number of occasions at the end of seven days; but they usually decrease rapidly after three days.

Twelve attempts have been made to secure pure lines by isolating single individuals. The findings agree with those of Barret and Yarbrough that this can not be done by the drop culture method. The organisms appear to be anaerobic. Success was obtained by picking out single individuals with a micropipette, placing into a drop of culture fluid on a cover slip and dropping the latter into a test tube containing the medium. On one occasion multiplication occurred but the transplant failed.

After three unsuccessful attempts a culture was started with *Balantidium* from the guinea-pig in the same media as are used for the culture from the pig. This strain has now been successfully transplanted six times. The organisms ingest starch as does the pig *Balantidium* and become very active. It would be impossible to distinguish the trophozoites from those from the pig if the labels were left off the culture tubes. Occasional cysts have been found in tubes in which trophozoites from the guinea-pig have disappeared. Despite repeated research no cysts have been found in cultures from the pig.

Resistance of Trophozoites to Hydrogen Sulphide

The odor of H_2S is always pronounced in the feces of pigs. On five occasions this gas has been bubbled through culture tubes for fifteen to thirty seconds. No deleterious effects have been noted on the trophozoites. The first time that the experiment was tried the culture from the pig lived seven days. It was hoped that this gas might be used to check the growth of harmful bacteria. Subsequent results were so variable that no conclusions are justified. H_2S was found toxic to the trophozoites when bubbled through feces of the pig; when treated and untreated samples were kept in the incubator the organisms disappeared in forty-eight hours from the treated tubes but lived seventy-two hours in the untreated material.

Summary

It has been shown that trophozoites of balantidia from the pig are normal in appearance and reactions when the medium is cooled to room temperature. They may live at room temperature for ten days. Trophozoites that infect the pig may pass through the stomach of the guinea-pig and reach the cecum, where they are normal after eighteen hours. Trophozoites are frequently passed in feces by the pig but cyst production is irregular and determined by unknown factors as in monkeys, guinea-pigs and man. The fluid of pig feces from the cecum is slightly hypertonic to blood serum. The method of Barret and Yarbrough for the cultivation of *Balantidium coli* has been found practicable for *Balantidium* from the pig and guinea-pig. The addition of rice starch improves the medium and Ringer's solution without dextrose was found more suitable than 0.5 per cent. NaCl solution. Loeffler's beef blood serum may be substituted for human serum or horse serum. H_2S appears non-toxic to *Balantidium* from the pig when passed into culture tubes.

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